Synthetic Environments Program

TAOS:
Synthetic Natural Environments for Distributed Simulations

Multiresolution Simulation Environments Workshop

13 August 1996

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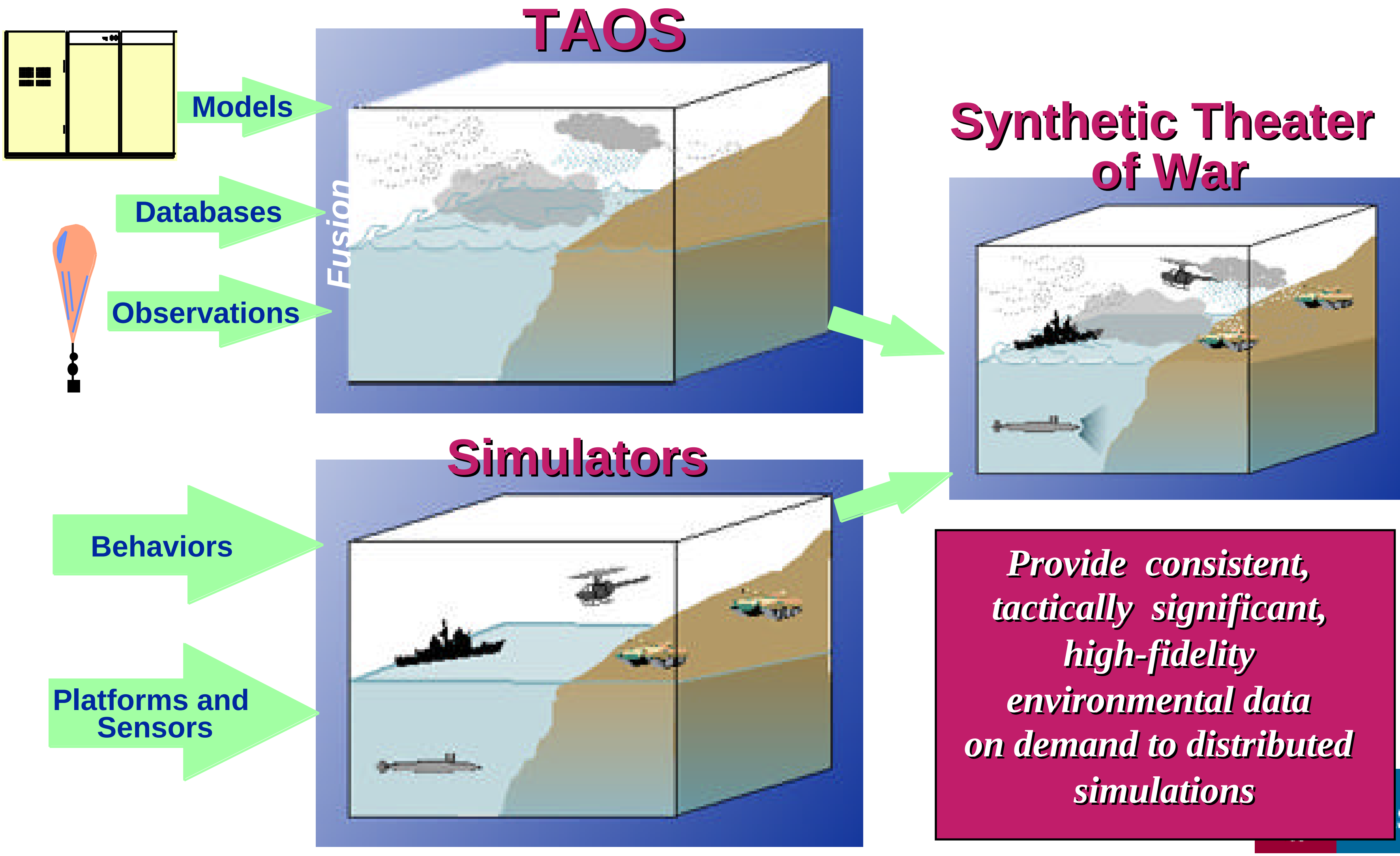
Outline

- TAOS (Total Atmosphere-Ocean Services) System Overview
- Implementation Experiences
- General Multiresolution Issues
- Summary

Creating the Synthetic Battlespace

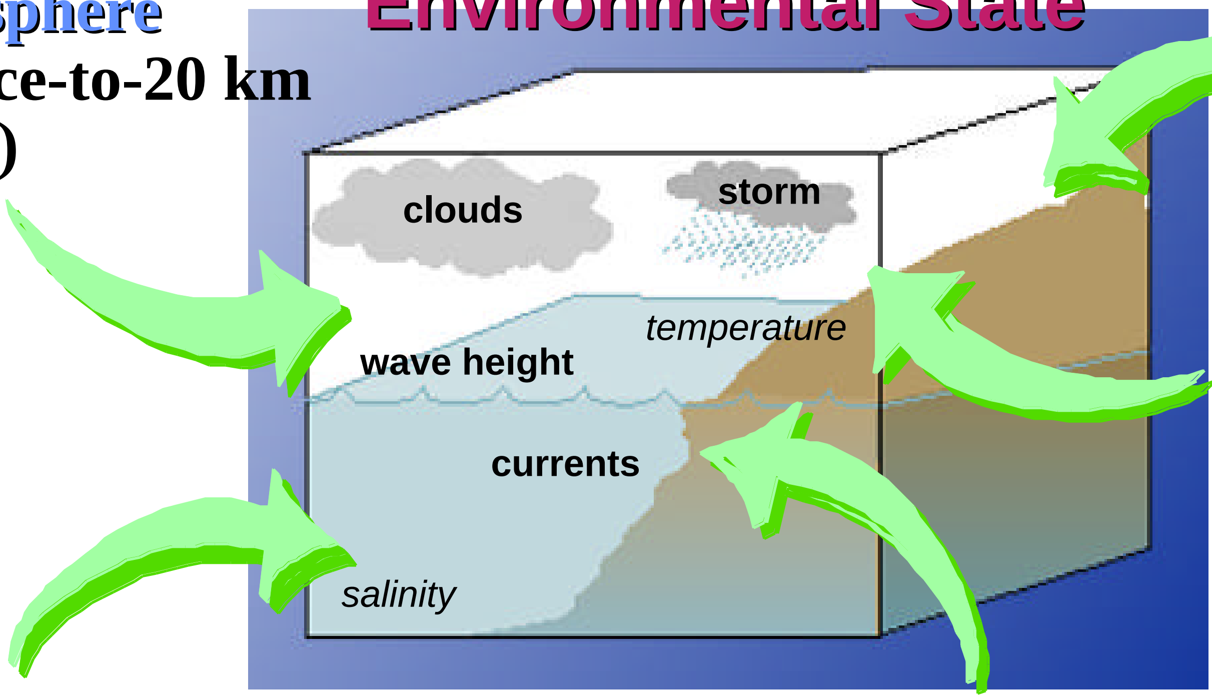


Provide consistent, tactically significant, high-fidelity environmental data on demand to distributed simulations

Data Regimes Currently Supported

Dynamic 4-D Environmental State

Atmosphere (surface-to-20 km height)



Space (extrapolated atmosphere)

Embedded **feature** models

Ocean surface, volume, and bottom characteristics (> ~10 m depth)

Littoral / surf zone (< ~10 m depth)

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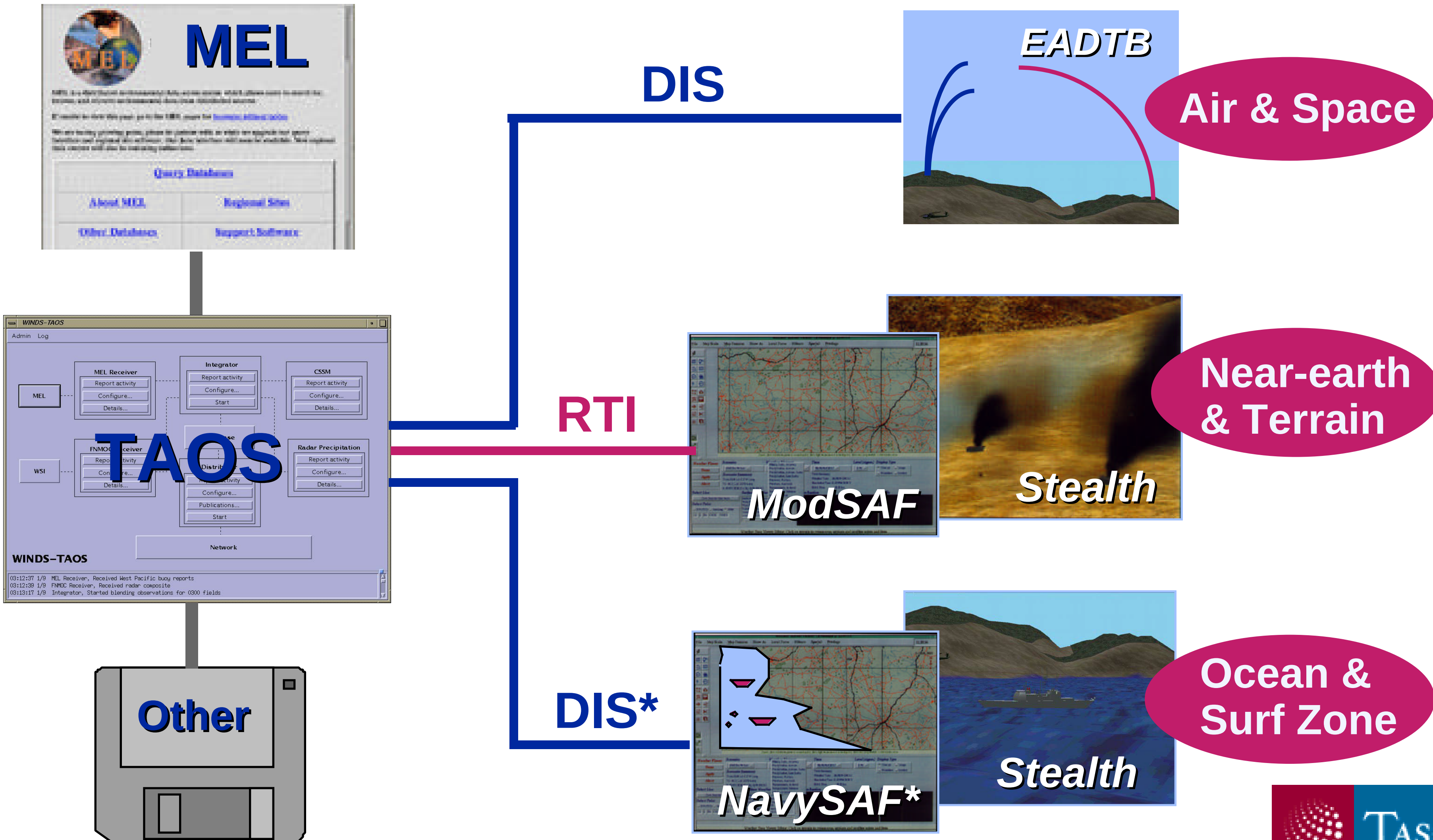
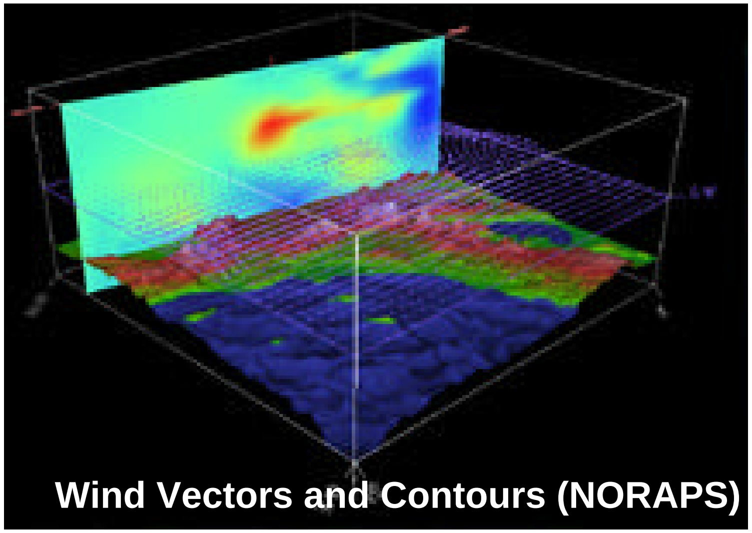
Upcoming Application Integration Plans

Preliminary



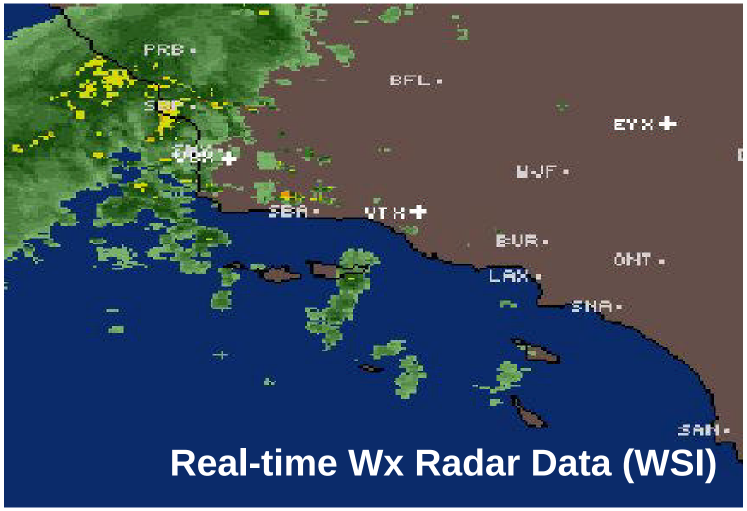
*Tentative

TAOS SYNTHETIC ATMOSPHERE ENVIRONMENT EXAMPLES

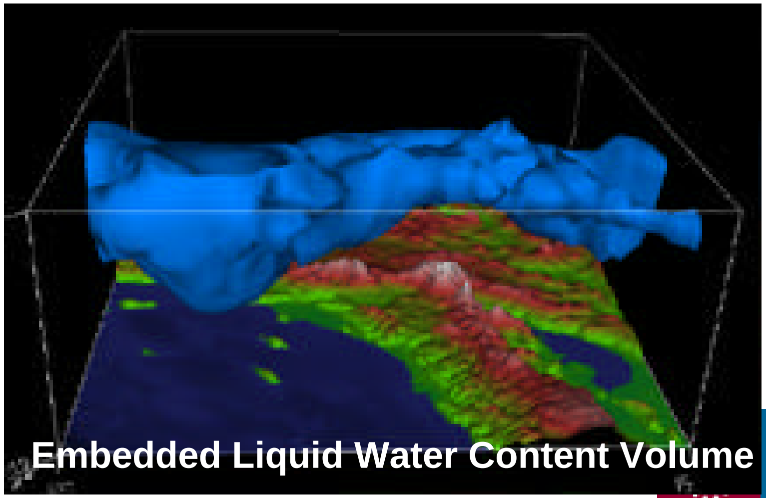


Wind Vectors and Contours (NORAPS)

Wind Effects on Smoke Plumes



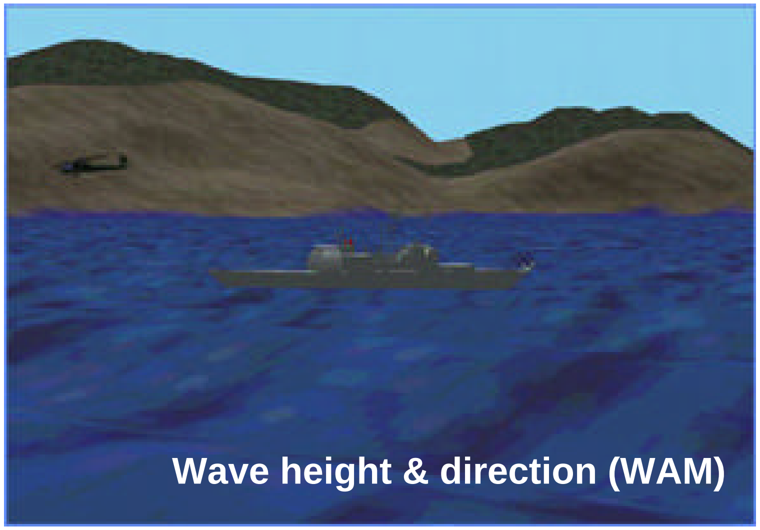
Real-time Wx Radar Data (WSI)

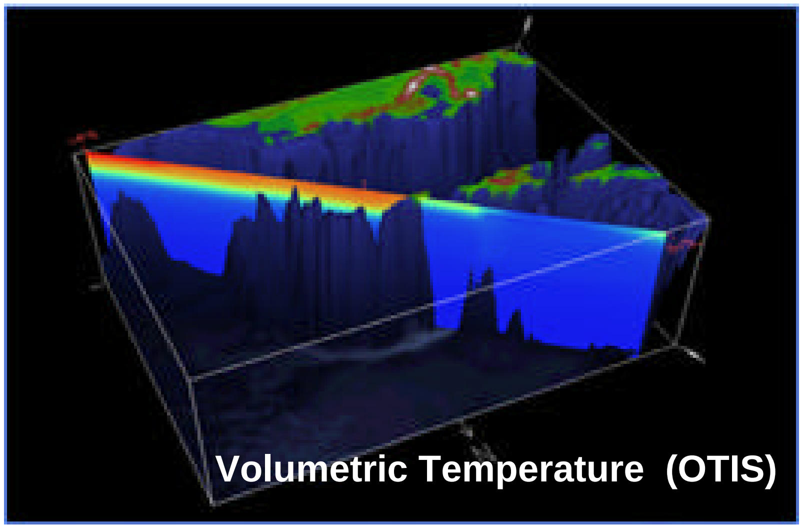


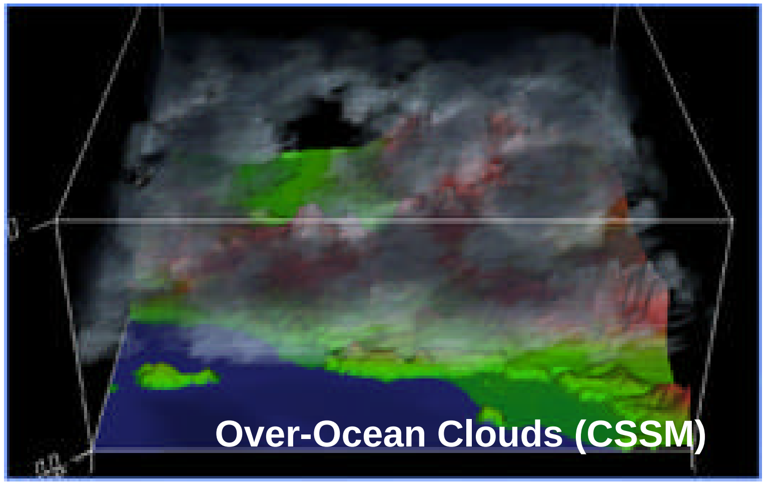
Embedded Liquid Water Content Volume

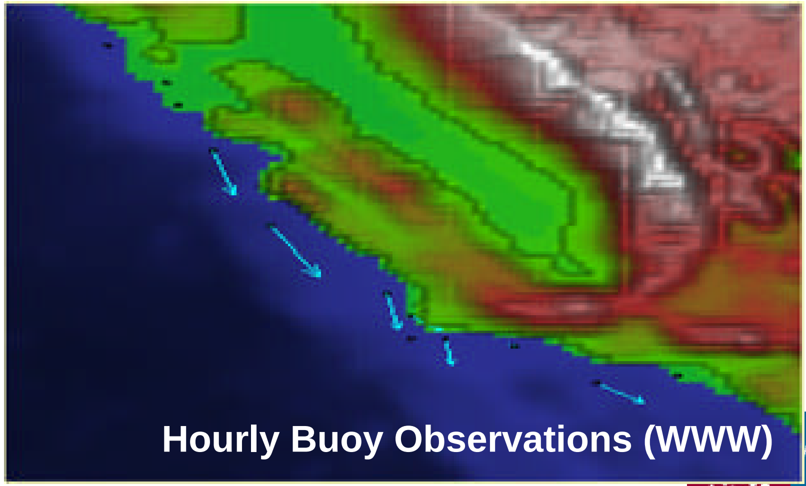
TAOS SYNTHETIC OCEAN ENVIRONMENT EXAMPLES

Synthetic Environments *Environmental M&S*









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Archived Ocean/Atmosphere Data

Extended SWUS, January 1995 Scenario

Dataset	*Spatial Resolution*	*Temporal Resolution*	*Variables*
NSSM	point	6 hr	surf zone forecast
STWAVE	100 m	6 hr	wave spectra
PWC	0.08°-0.12° (~7-13 km)	3 hr	T, U, V, W, salinity, sea surface ht
WAM	0.05° (~6 km)	6 hr	sig. wave ht., primary wave period and direction, swell period, sig. swell ht and period of swell
OTIS	0.2° (~20 km)	12 hr	T, salinity
NORAPS	20 km	1 hr	T, U, V, precipitation, pressure, mixing ratio
COAMPS	(5, 15, 45 km) nested grid	3 hr	T, U, V, u and v wind stress, total heat flux, pressure, precipitation, latent & sensible heat flux, solar radiance, potential T, mixing ratio
ADCIRC	0.05°(~6 km)	12 hr	U, V, sea surface height

Operational Products for SE4
Ocean/Atmosphere Models

Dataset	***Spatial Resolution***	***Temporal Resolution***	***Variables***
AWN	point	1-3 hr	atmosphere and ocean obs
WAM	1.25° (~135 km)	12 hr	primary wave direction, significant wave height
OTIS	~190.5 km	12 hr	T, U, V
TOPS	~190.5 km	12 hr	T, U, V
NOGAPS	2.5° (~270 km)	6 hr	T, U, V, Pressure, geopotential ht, absolute vorticity, vapour pressure, total cloud cover
NORAPS	0.2° (~22 km)	6 hr	T, U, V Pressure, vertical velocity, geopotential height

- **Model products will define MEL SE4 data requirements**
- **Variables or derivatives will meet currently planned DVW and EADTB data requirements**

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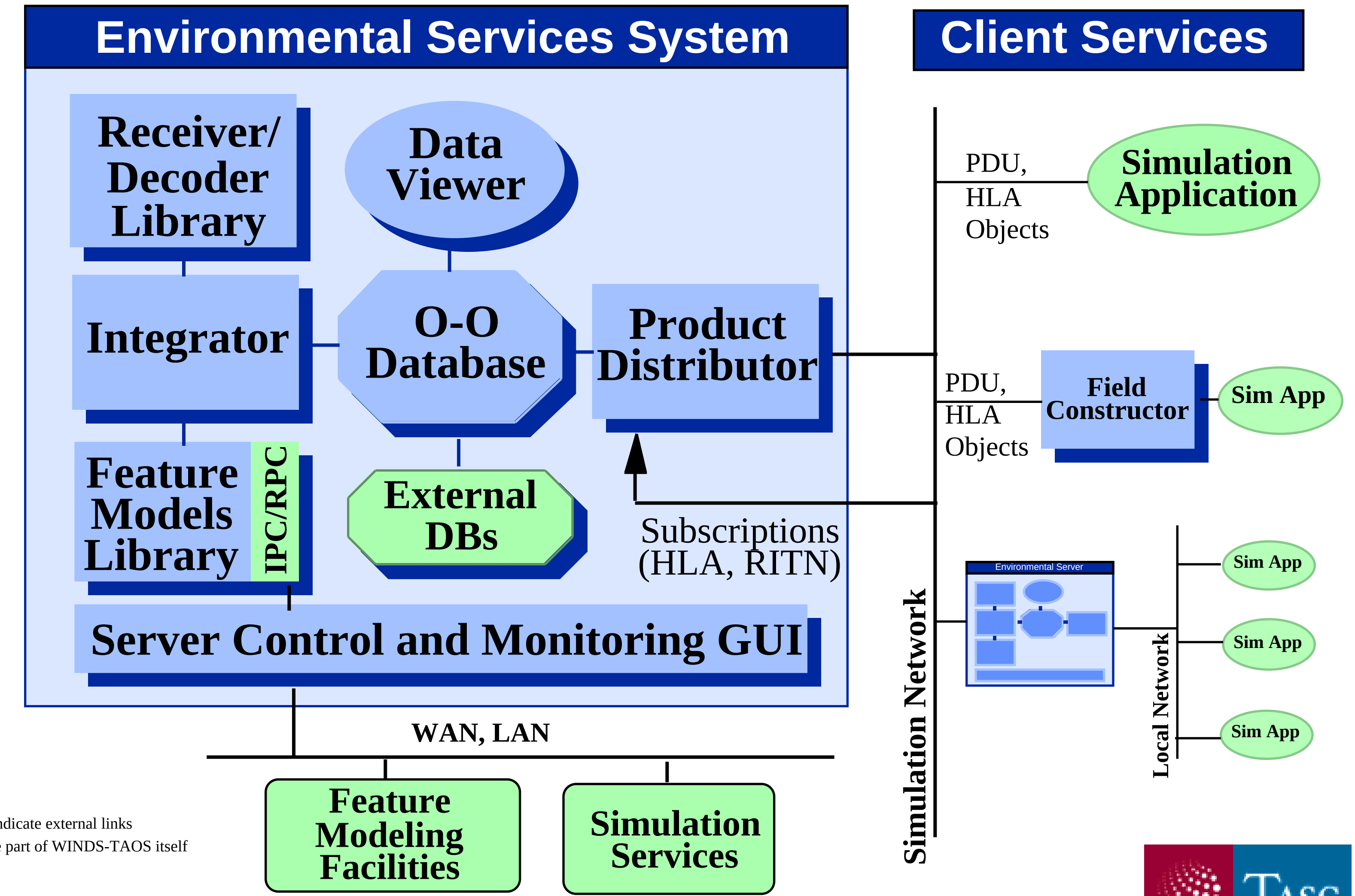
TAOS Architecture Overview

Synthetic Environments — *Environmental M&S*

Data

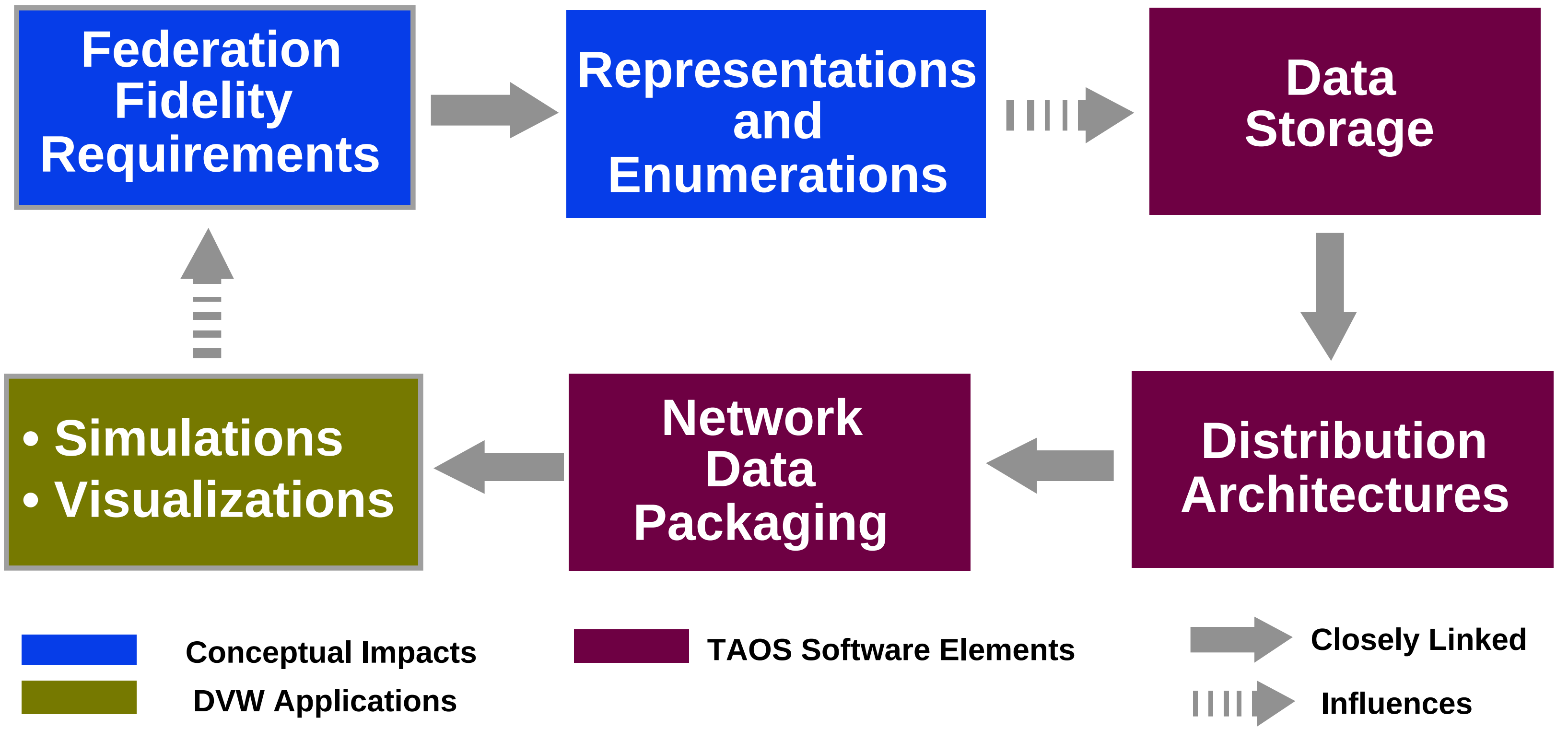
- Ocean, Atmosphere, Terrain
- Forecast, Climatology, Historical
- Battlespace measurements: Surface, Soundings, Radar, Satellite
- Fields, Time History



Green elements indicate external links
Blue elements are part of WINDS-TAOS itself

Where Multiresolution Issues Arise

A TAOS Implementation Perspective



- Different strategies applicable at each stage
- TAOS is work in progress -- concepts are being expanded, modified as development advances

Multiresolution Issues Addressed

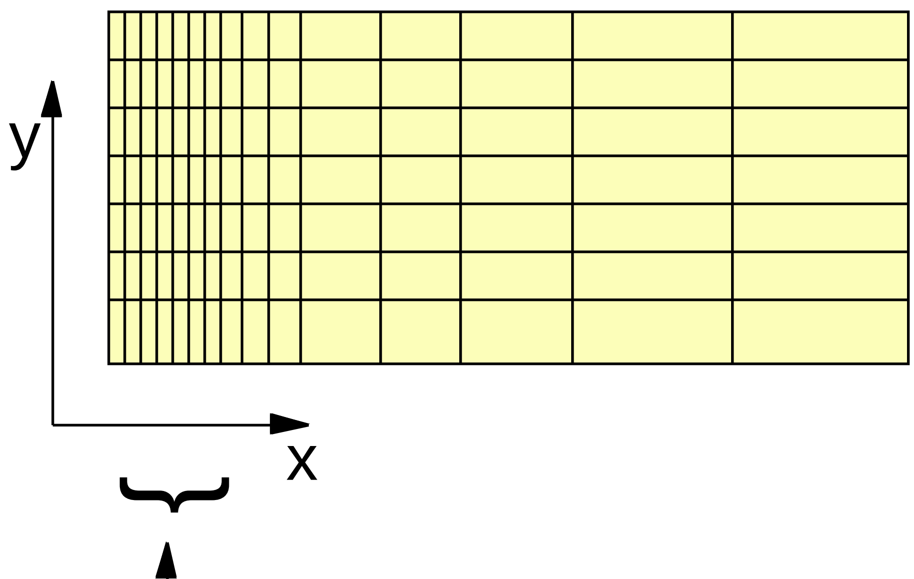
- Selected TAOS Multiresolution Implementation Experiences
  - Storing variably-spaced environmental fields
  - Distributing subsampled mixed resolution 2D grids
  - Distributing variably-spaced gridded 3D data fields
- Concepts for Future Developments
  - Oct-tree-based representations
  - Application of digital signal processing techniques
- Fidelity Enumerations

Note: TAOS support is primarily for 3-D data, but illustrations herein are generally 2-D for clarity

Variably-spaced Rectangular Grid Storage

Aim: Store Data Only at the Resolutions its Needed

Variably-spaced rectangular grids:



High sample density for x in this range, independent of y

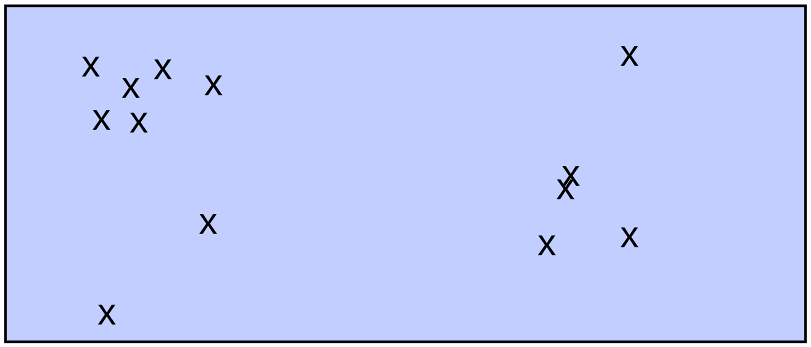
Pro

- Grid geometry is compactly described
- Data structure supports efficient queries
- Interpolation methods well-known

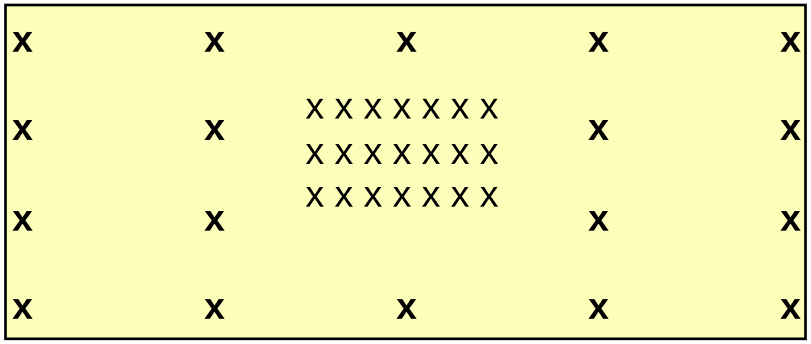
Con

- High sample-density imposed on regions that do not necessarily require it

Using Arbitrarily Spaced “Observers”
Provides Mixed Resolution Data Distribution



- **As used by ModSAF 2-D Live Wx model ...**
- **“Observers” are actual surface obs stations**



- **As used by TAOS’ Live Radar-derived Precip Model ...**
- **“Observers” are samples extracted from a gridded dataset**
- **Variable resolution patches are provided**

Pro

- Naturally supports multiple-resolution data
- Simple memory representation (list of location-value sets)

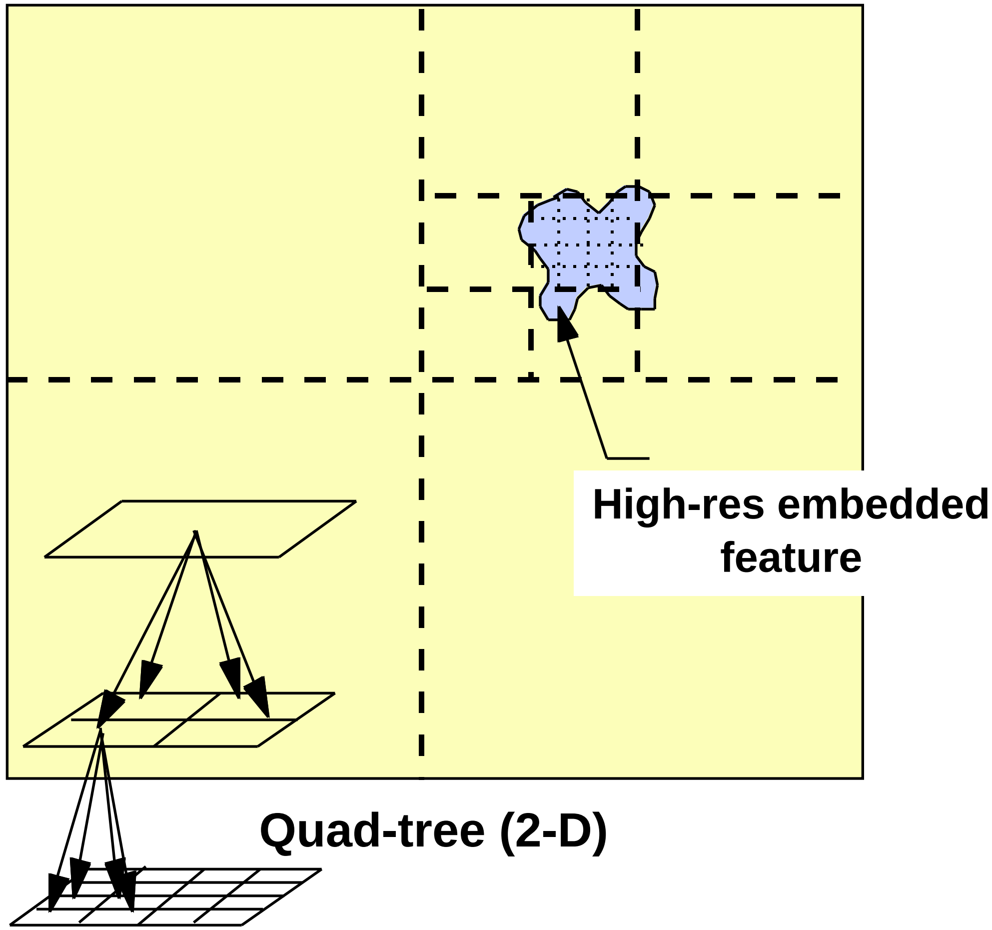
Con

- Spatial interpolation difficult; gridded data operations do not apply
- Memory/performance problems for large number of observers

Tree Structures for Efficient Storage

Especially for Sparse High-res Features

Tree-based Representations



Quad-tree (2-D)

- Effects a multi-resolution rectangular grid (with constraints)
- Doesn't oversample areas of low resolution
- Extension of Quad-tree techniques used for terrain representation (features, aggregation)

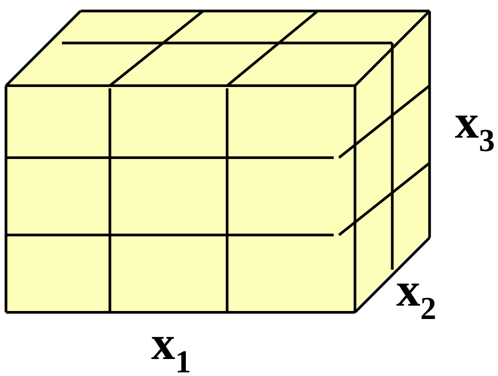
Gridded Data Structure

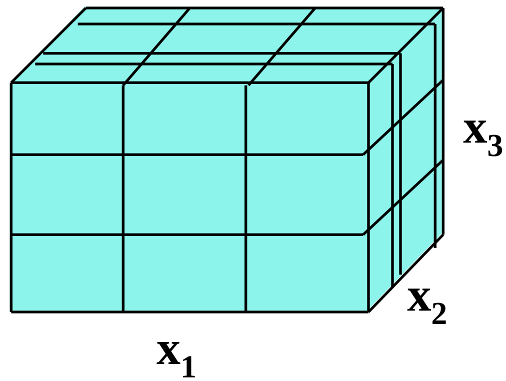
New Functionality for Environmental Data Delivery

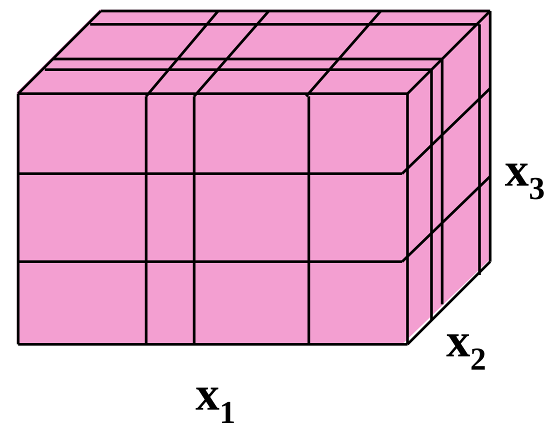
New challenges are presented by large, gridded, non-uniform resolution environmental data sets

- Transmit large amounts of environmental data, with extensible data representation schemes
- Provide robust sampling method to allow “dead-reckoning” when data voids/loss occur
- Provide a simple, efficient data packing mechanism
- Define the protocol for transmitting n-D grids, including an index, coordinate system, sample enumeration, Euler angles, scalar vs vector data and sequential order
- Allows sampling of n-D space vertically or horizontally
- Extensible sample and coordinate enumerations
- Compatible with the TAOS Distributor and the ModSAF PDUAPI
- Developed in coordination with the DIS standards process

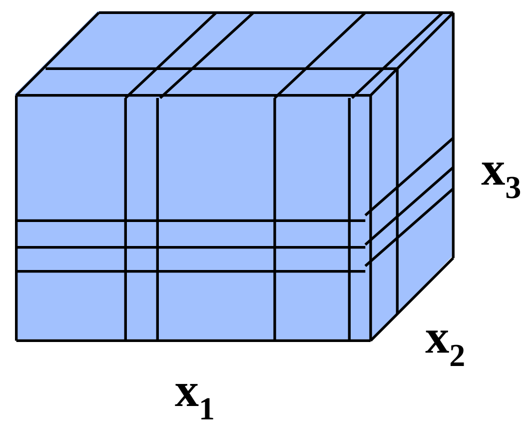
Efficient Packing of Variable Resolution Data Grids



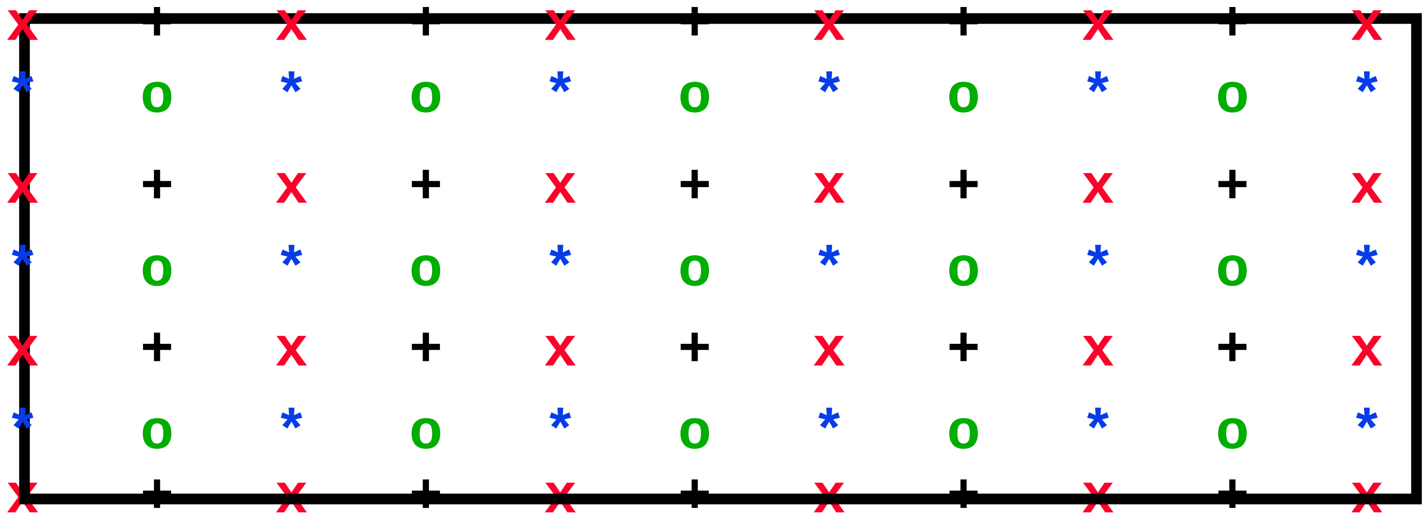




- "Predictable" variable resolution in any of N dimensions is supported
- Efficient indexing schemes take advantage of economies presented by grid structure
- Extensions to include non-gridded embedded features have also been studied



Gridded Data PDU Data Interleaving Facilities



Tile 1 is x

Tile 2 is +

Tile 3 is *

Tile 4 is o

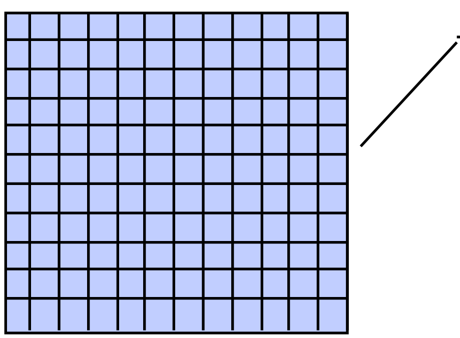
- Provides the sim client capability to fill data voids caused by missing data
- Allows efficient combination of data at different resolutions within a single data packet (see subsampling discussion that follows)

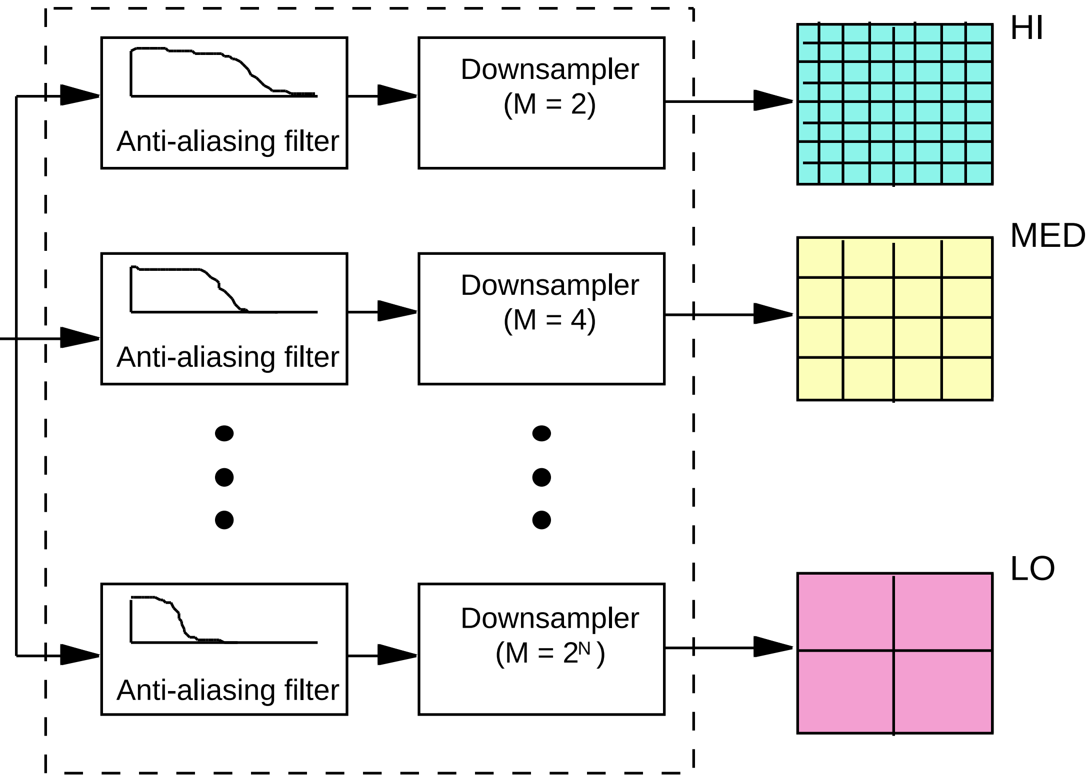
Consistent Representation at Variable Resolutions

Application of Digital Signal Processing (DSP) Techniques

Multiresolution Fields:

- **Ground-truth field on regular grid**
- **Built by TAOS Integrator**
- **Stored in TAOS Database**
- **Represents highest-resolution field**



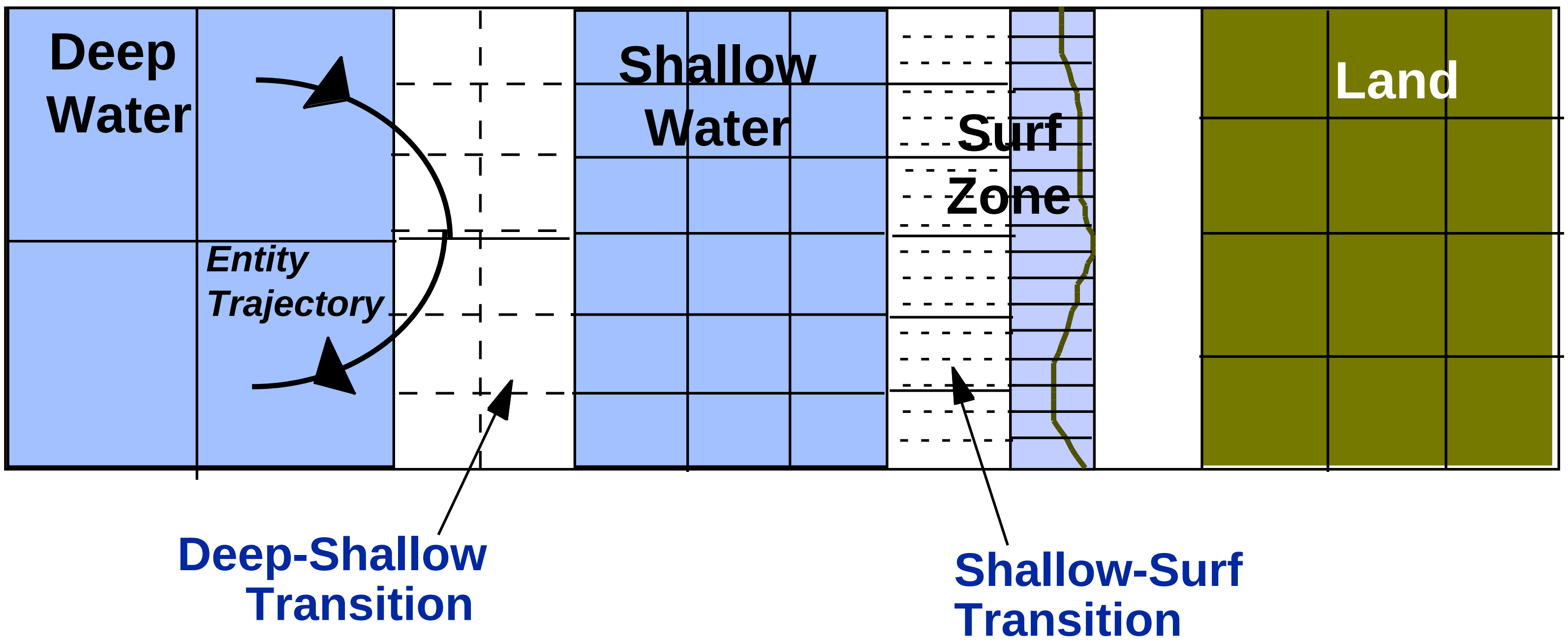


Distribution Concept:

- **Use Gridded Data PDU's *interleaved grid* representation option**
- **Simulation applications (clients) requiring only low res data ignore all but *leaf 1***
- **Simulation applications requiring medium res data add *leaves 1 and 2,* ignore leaf 3**
- **Simulation applications requiring high res data *add all leaves***

Merging Data at Different Resolutions

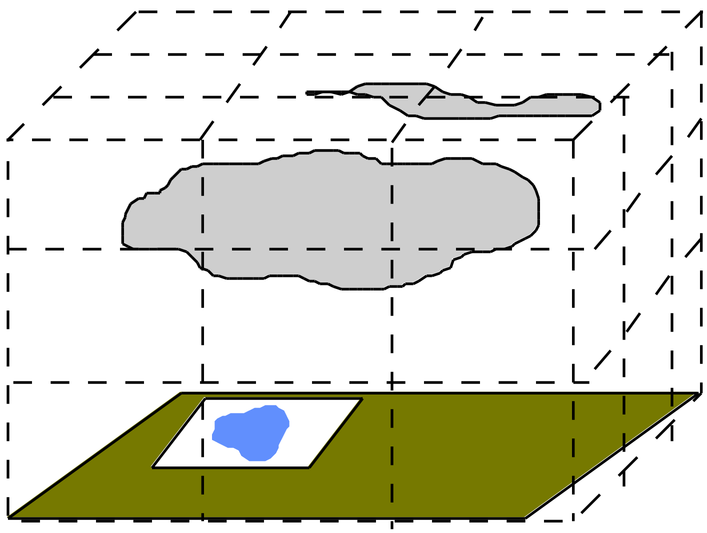
Aim: Avoid "Over-delivery" of Data to Sim Client



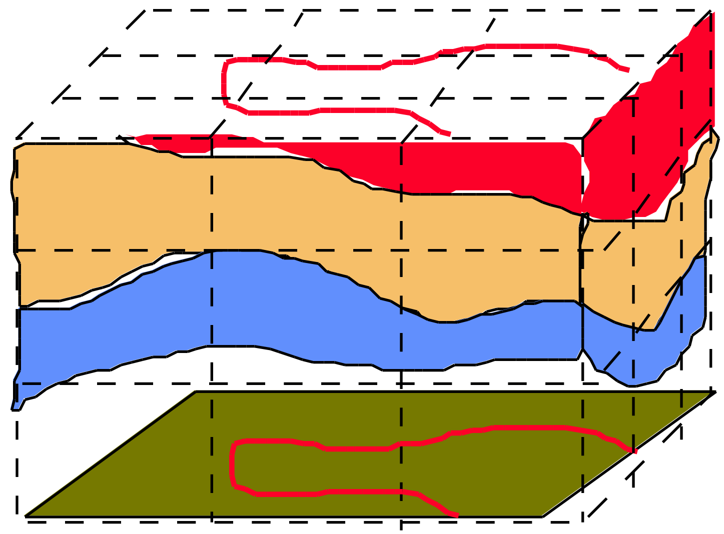
- Provide overlapping data at two resolutions at the transitions ("seams")
- Client simulation that will operate mainly in one resolution region need not handle data that is at a higher resolution than it needs
- Representation of overlapping data sets must be consistent

Varying Complexity of Multiresolution Data
Features vs. Backround Fields

Feature or Embedded Process



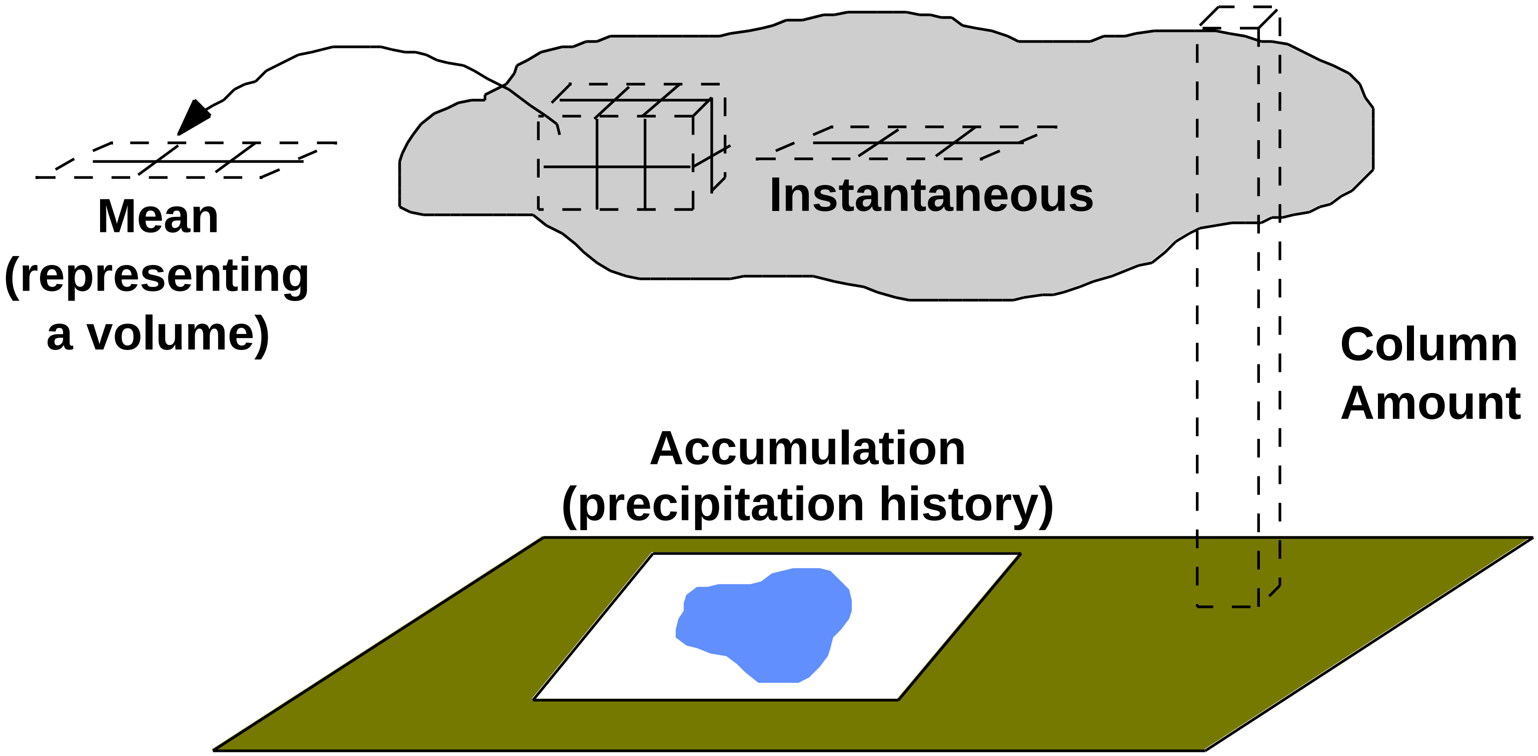
Base / Ambient Field



- Base fields vary more slowly in time, are more spatially uniform, and easier to predict
- Features or embedded processes are usually spatially and temporally localized, with important fine structure (e.g. clouds)
- Preseving correlation across multiple resolutions more difficult

Multiple Representations of the Same Data

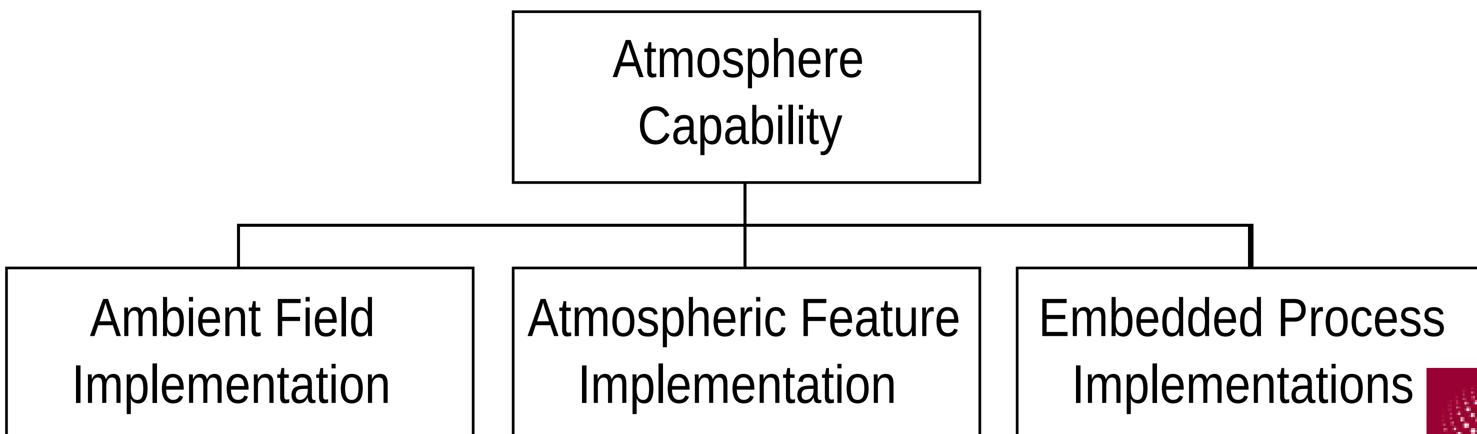
Example: Precipitation Information



- Multiple representations associated with variables
- Multi-resolution data for some representations
    - Accumulation over different time spans
    - Instantaneous measurements at different scales

Atmospheric Fidelity Representations

- Enumerations: for data filtering/translation on the network
  - Hierarchical structure for Interest Management (e.g. information filtering)
- SEDRIS: for dataset format translation/interchange
- Many alternative object models and representations exist
- Participation in DIS-STD-ATM Atmospheric Fidelity Enumeration document
  - Tiger Team members from NRL-Monterey (Atmos. WG chair), DEEM and TAOS



Summary

- METOC data presents some unique multiresolution representation and distribution issues
  - Both temporal and spatial multi-resolutions
  - Dynamic, localized features
  - Large 3-D grids for high-resolution data
- Single high-resolution database proposal appealing, especially wrt feature models -- practicality an issue
  - Would involve signficant network loading and distrubution issues for METOC data with its time-varying nature and potentially large spatial volumes
- Some areas for future research
  - Integrating multiresolution features and grids (indexing, storing)
  - Tradeoffs between uniform hi-resolution METOC fields and network/simulator computational loads
  - What characteristics shopuld be preserved across resolutions ? -- Metrics that provide coupling with sensor/component models

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